# EXHIBIT 10

US006849901B2

(12) **United States Patent**
**Falster**

(10) **Patent No.: US 6,849,901 B2**
(45) **Date of Patent: *Feb. 1, 2005**

(54) **DEVICE LAYER OF A SILICON-ON-INSULATOR STRUCTURE HAVING VACANCY DOMINATED AND SUBSTANTIALLY FREE OF AGGLOMERATED VACANCY-TYPE DEFECTS**

(75) Inventor: **Robert J. Falster**, London (GB)

(73) Assignee: **MEMC Electronic Materials, Inc.**, St. Peters, MO (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/038,084**

(22) Filed: **Jan. 3, 2002**

(65) **Prior Publication Data**

US 2002/0113265 A1 Aug. 22, 2002

**Related U.S. Application Data**

(62) Division of application No. 09/737,715, filed on Dec. 15, 2000, now Pat. No. 6,342,725, which is a continuation of application No. 09/387,288, filed on Aug. 31, 1999, now Pat. No. 6,236,014.

(60) Provisional application No. 60/098,902, filed on Sep. 2, 1998.

(51) **Int. Cl.**[7] ..... **H01L 27/12**; C30B 33/06

(52) **U.S. Cl.** ..... **257/347**; 117/3; 438/479

(58) **Field of Search** ..... 435/455; 257/347; 438/311, 423, 479, 480

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*Primary Examiner*—Anh Duy Mai
(74) *Attorney, Agent, or Firm*—Senniger Powers

(57) **ABSTRACT**

The present invention relates to a process for the preparation of a silicon on insulator wafer. The process includes implanting oxygen into a single crystal silicon wafer which is substantially free of agglomerated vacancy-type defects. The present invention further relates to a process for the preparation of a silicon on insulator wafer wherein oxygen is implanted into a single crystal silicon wafer having an axially symmetric region in which there is a predominant intrinsic point defect which is substantially free of agglomerated intrinsic point defects. Additionally, the present invention relates to a silicon on insulator ("SOI") structure in which the device layer and the handle wafer each have an axially symmetric region which is substantially free of agglomerated intrinsic point defects. Additionally, the present invention is directed to such SOI structure in which the handle wafer is capable of forming an ideal, non-uniform depth distribution of oxygen precipitates upon being subjected to the heat treatment cycles of essentially any arbitrary electronic device manufacturing process.

**3 Claims, 35 Drawing Sheets**

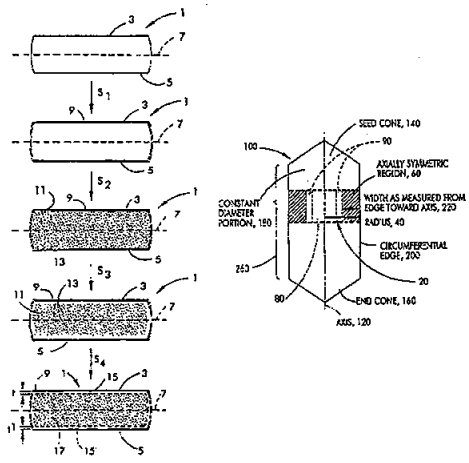

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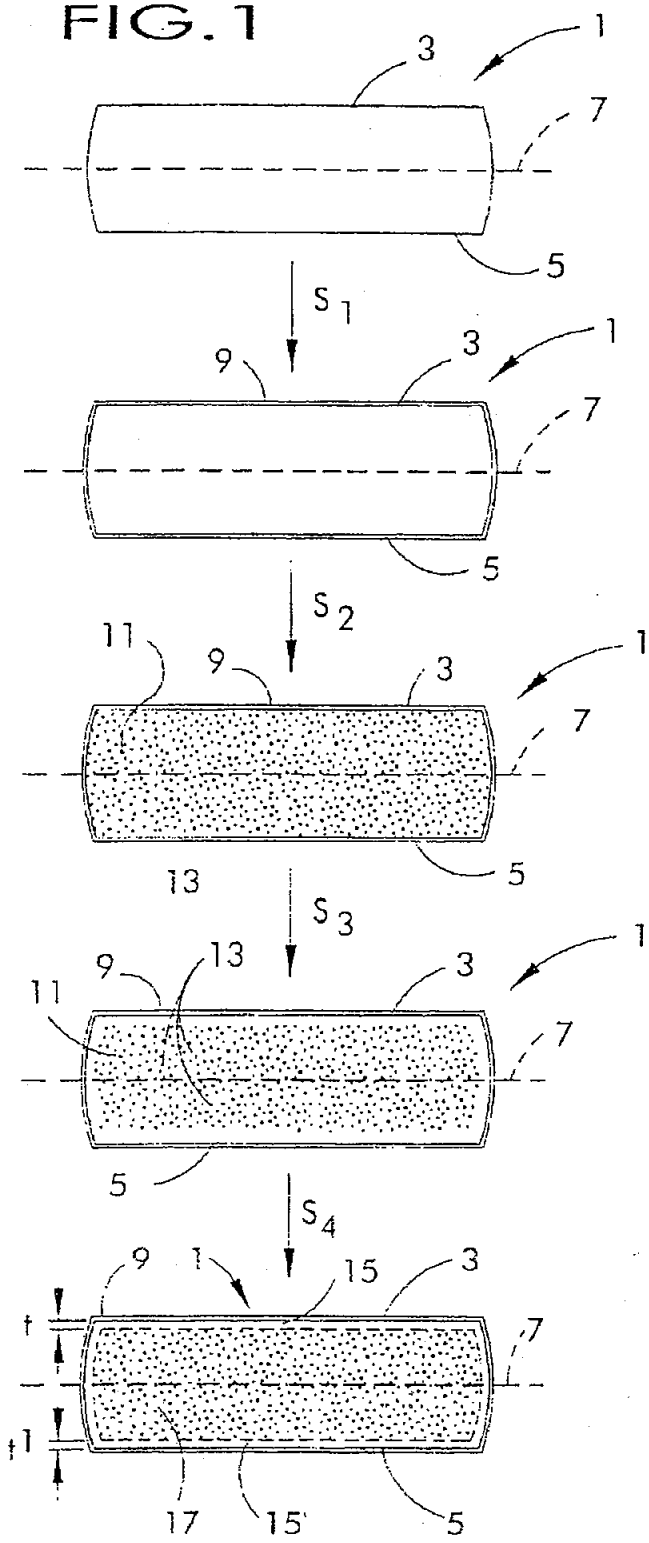
FIG. 1



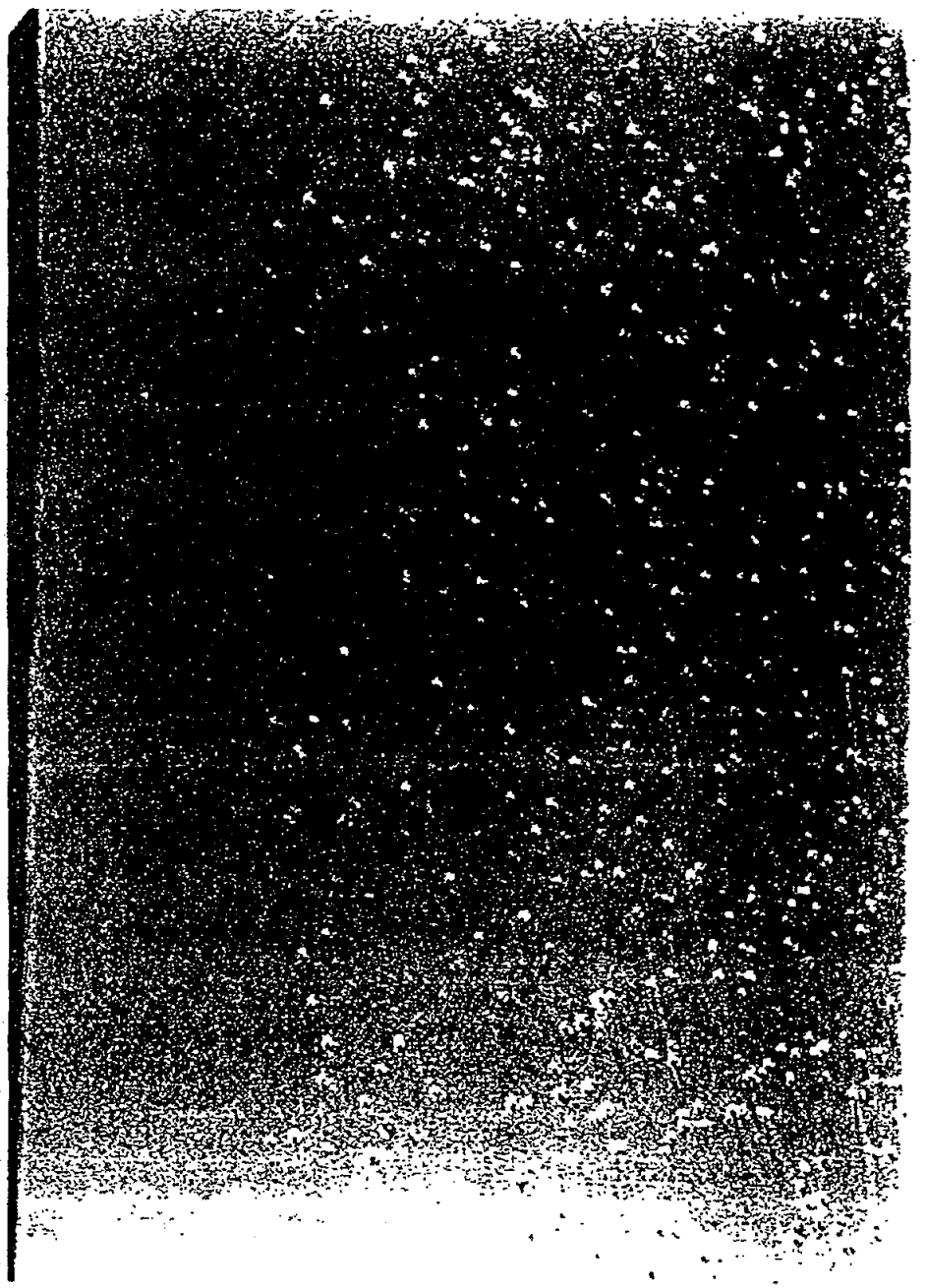


FIG.2

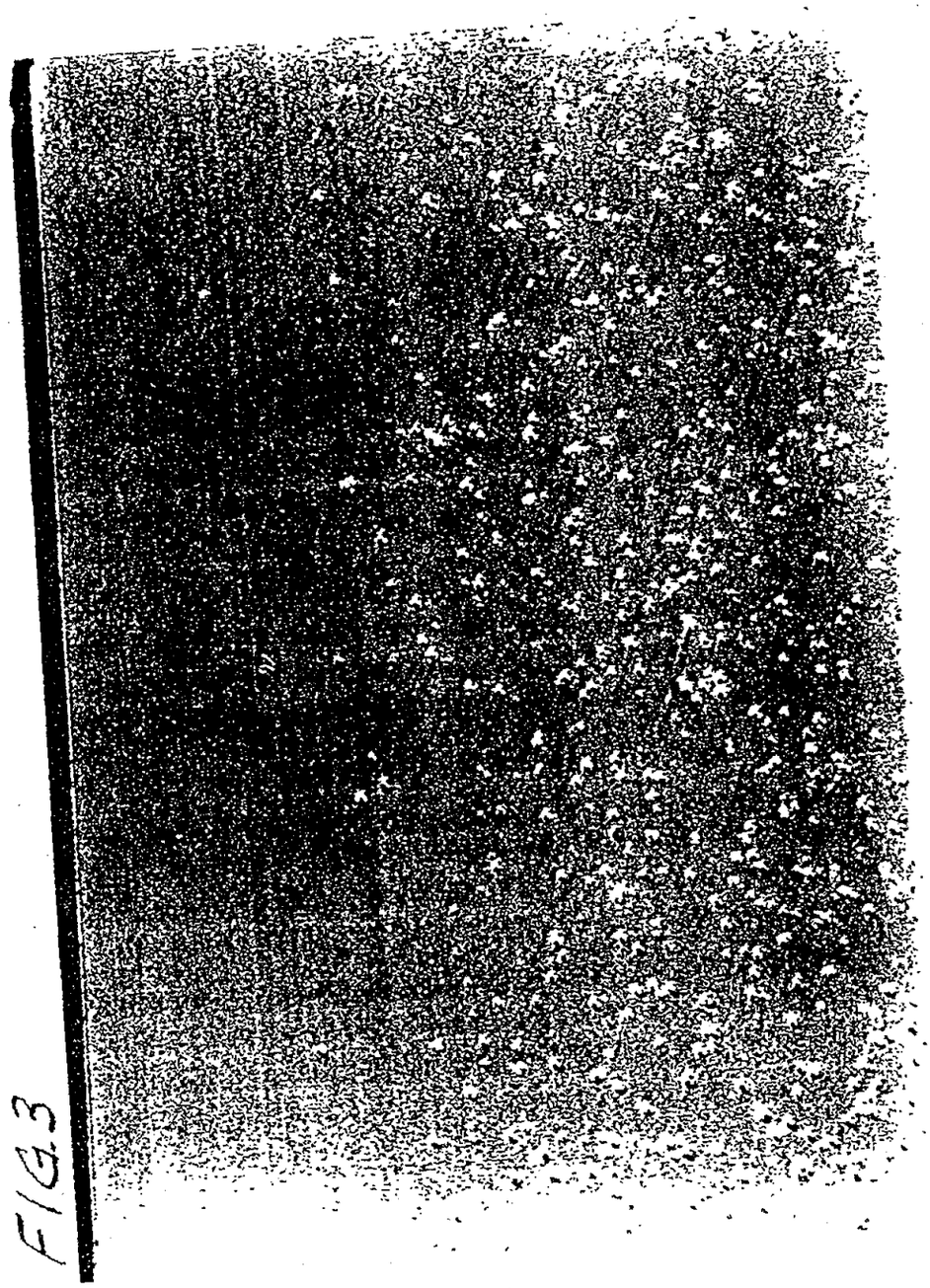


FIG.3

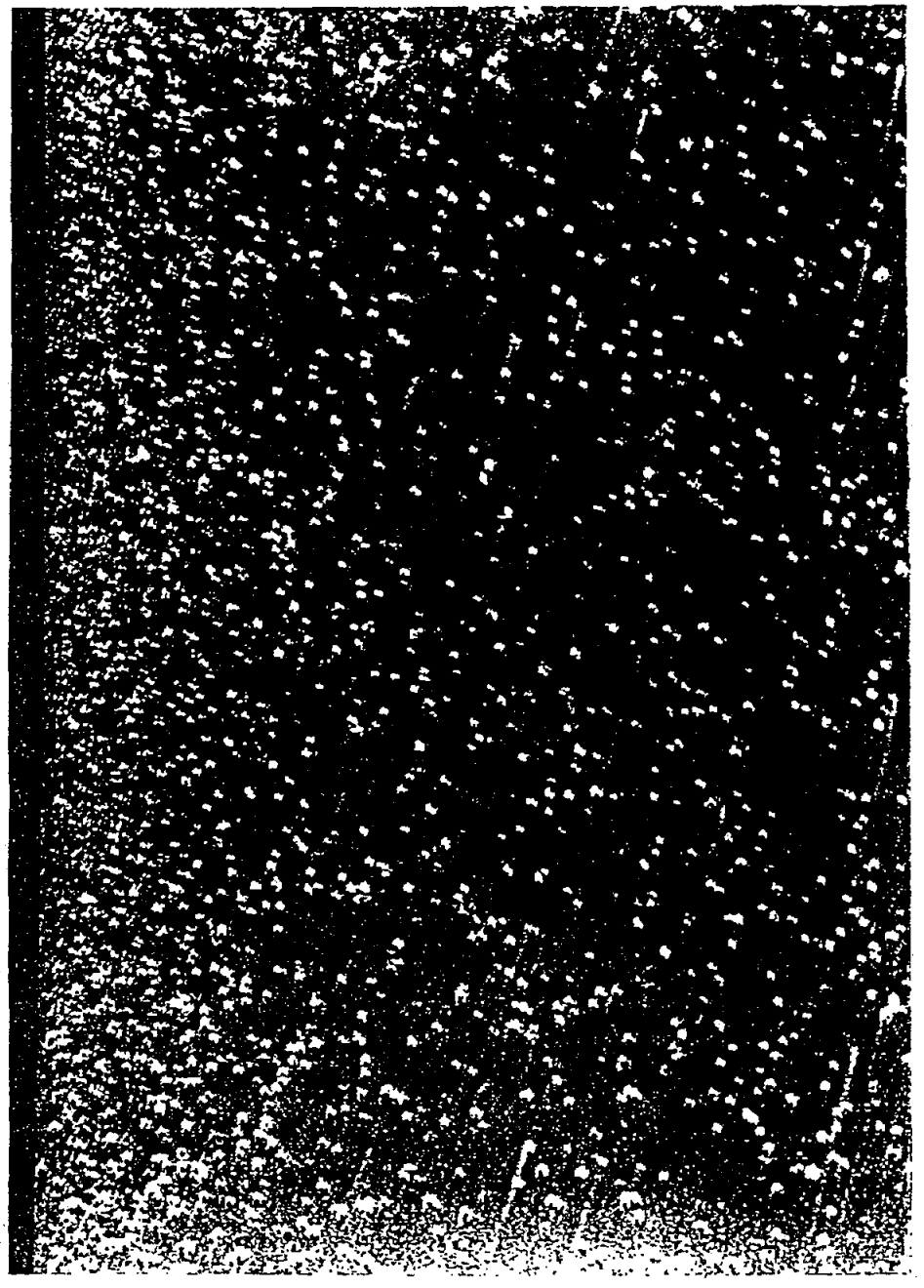
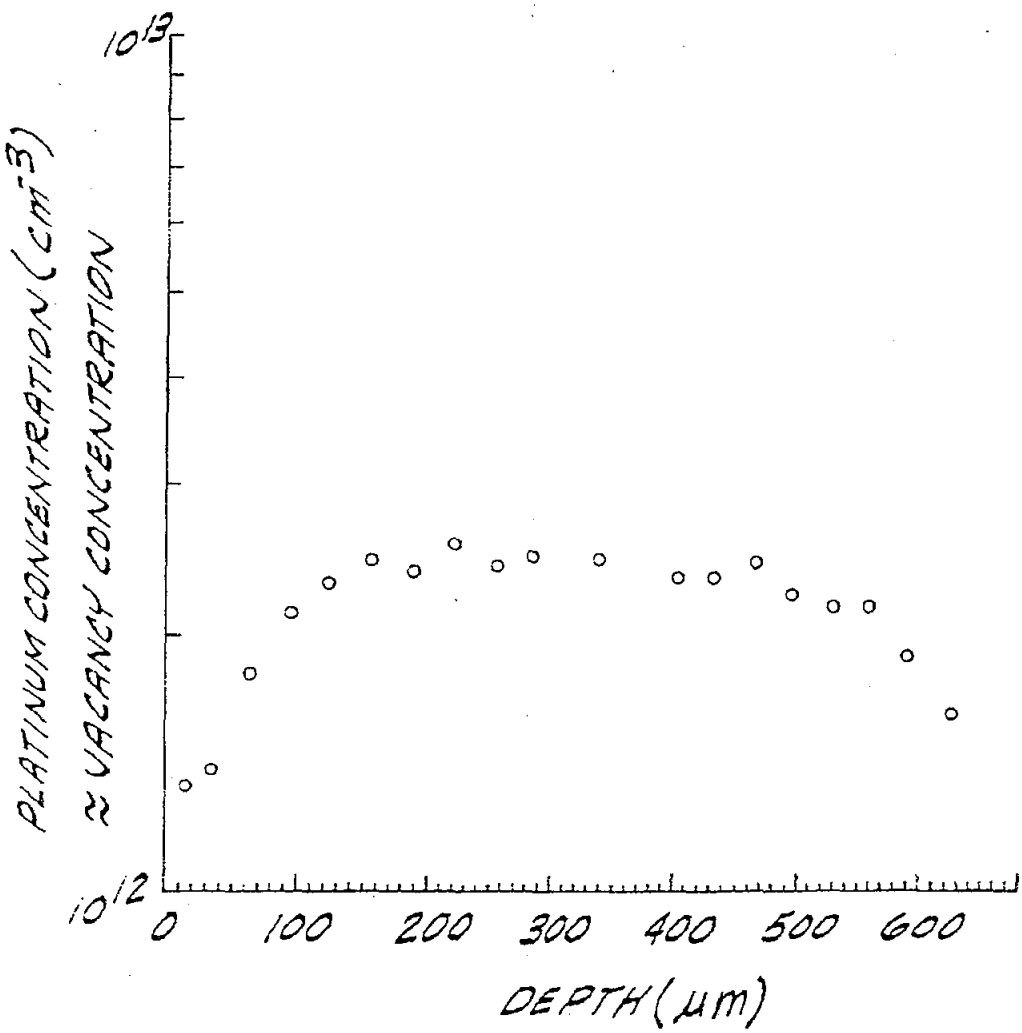
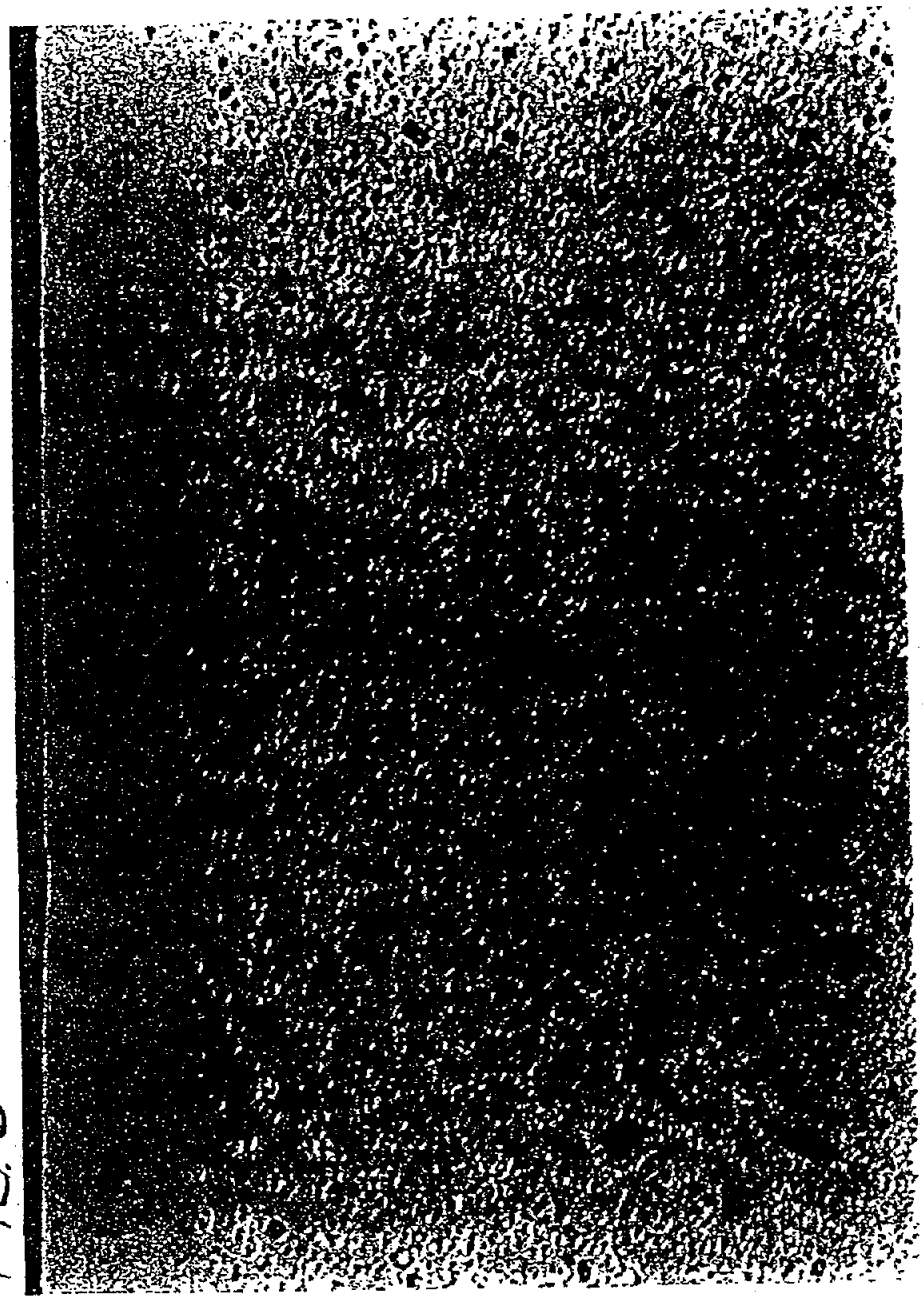


FIG. 4

FIG.5


PLATINUM CONCENTRATION (cm-3)
≈ VACANCY CONCENTRATION
10^13
10^12
0
100
200
300
400
500
600
DEPTH (μm)



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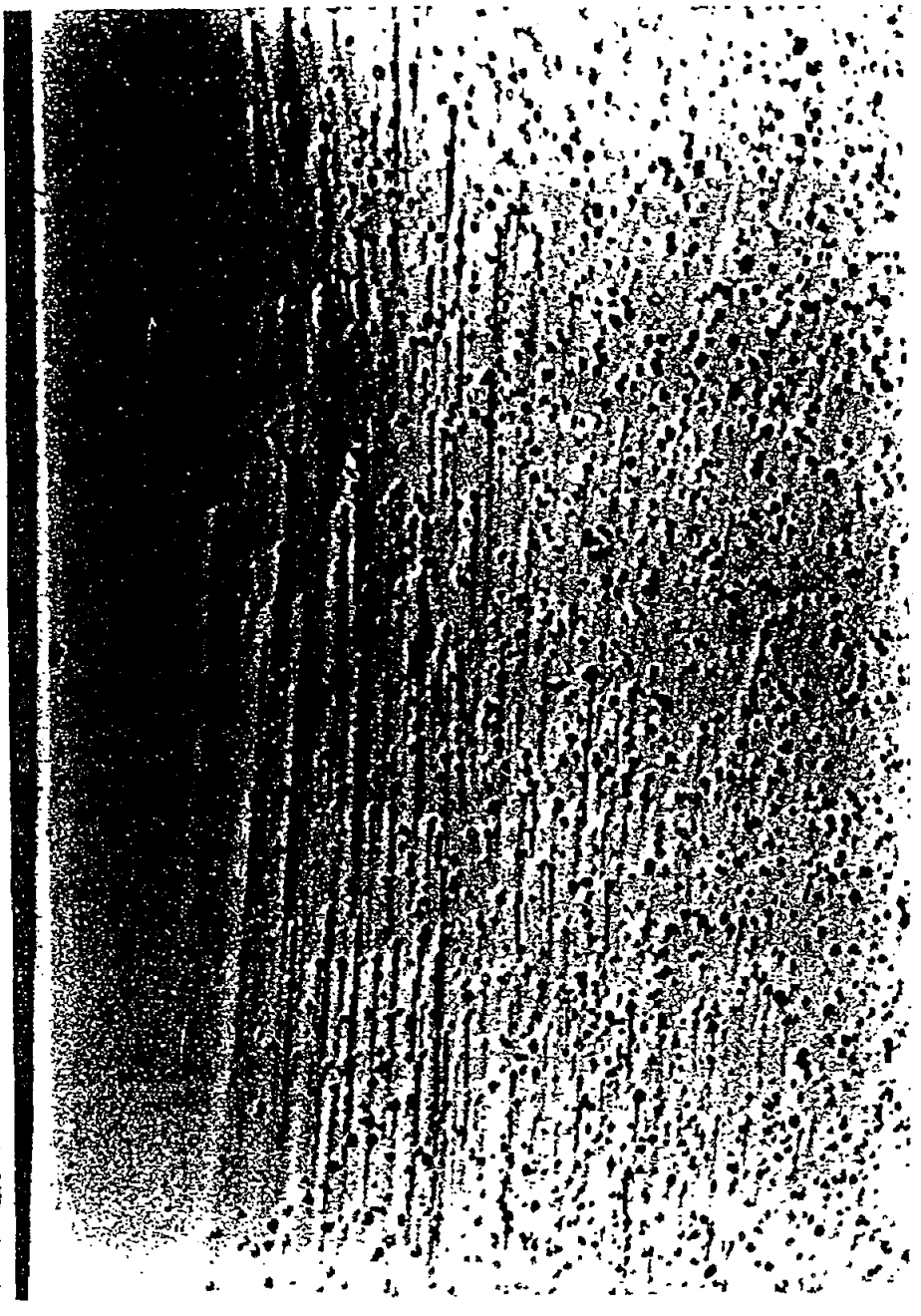

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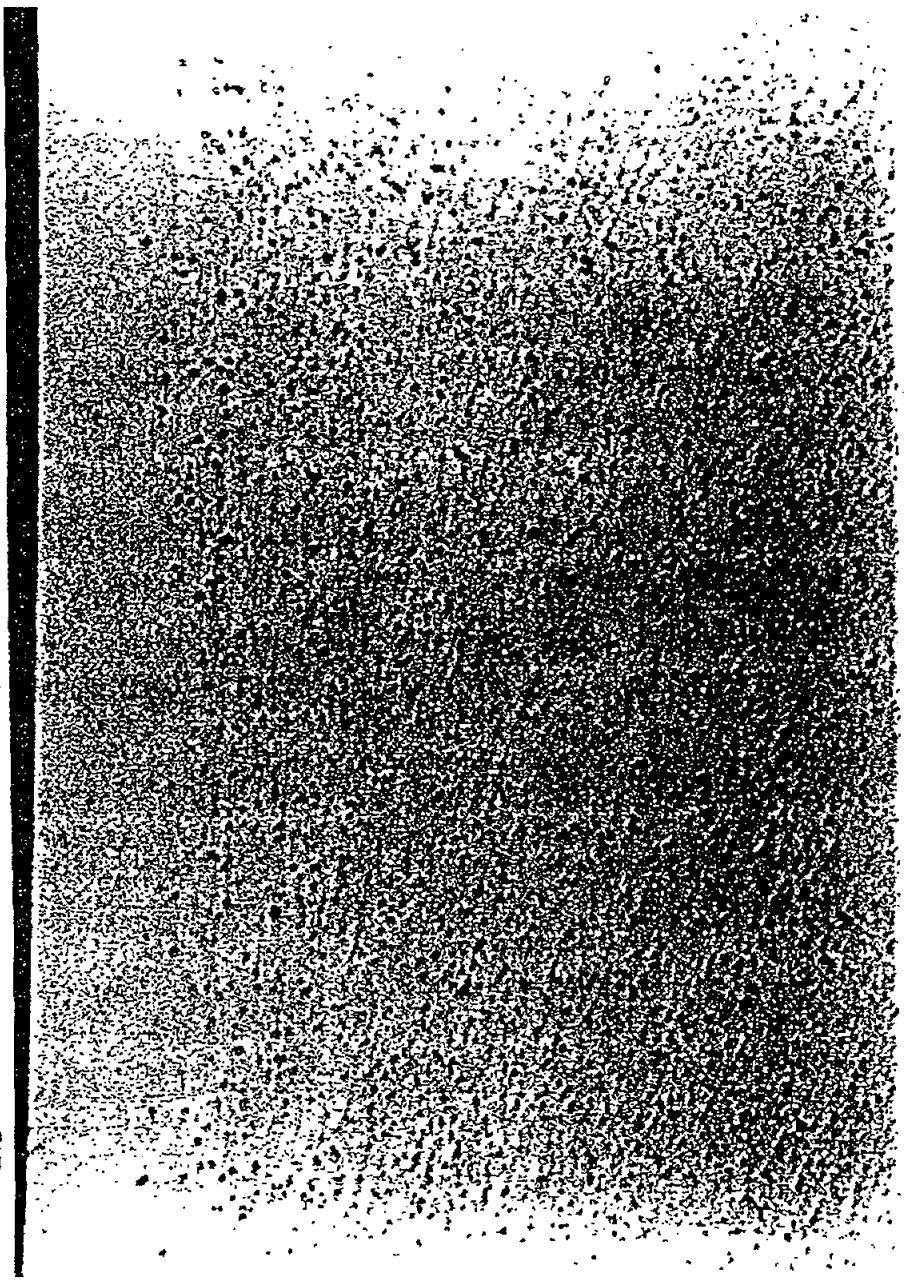


FIG. 8

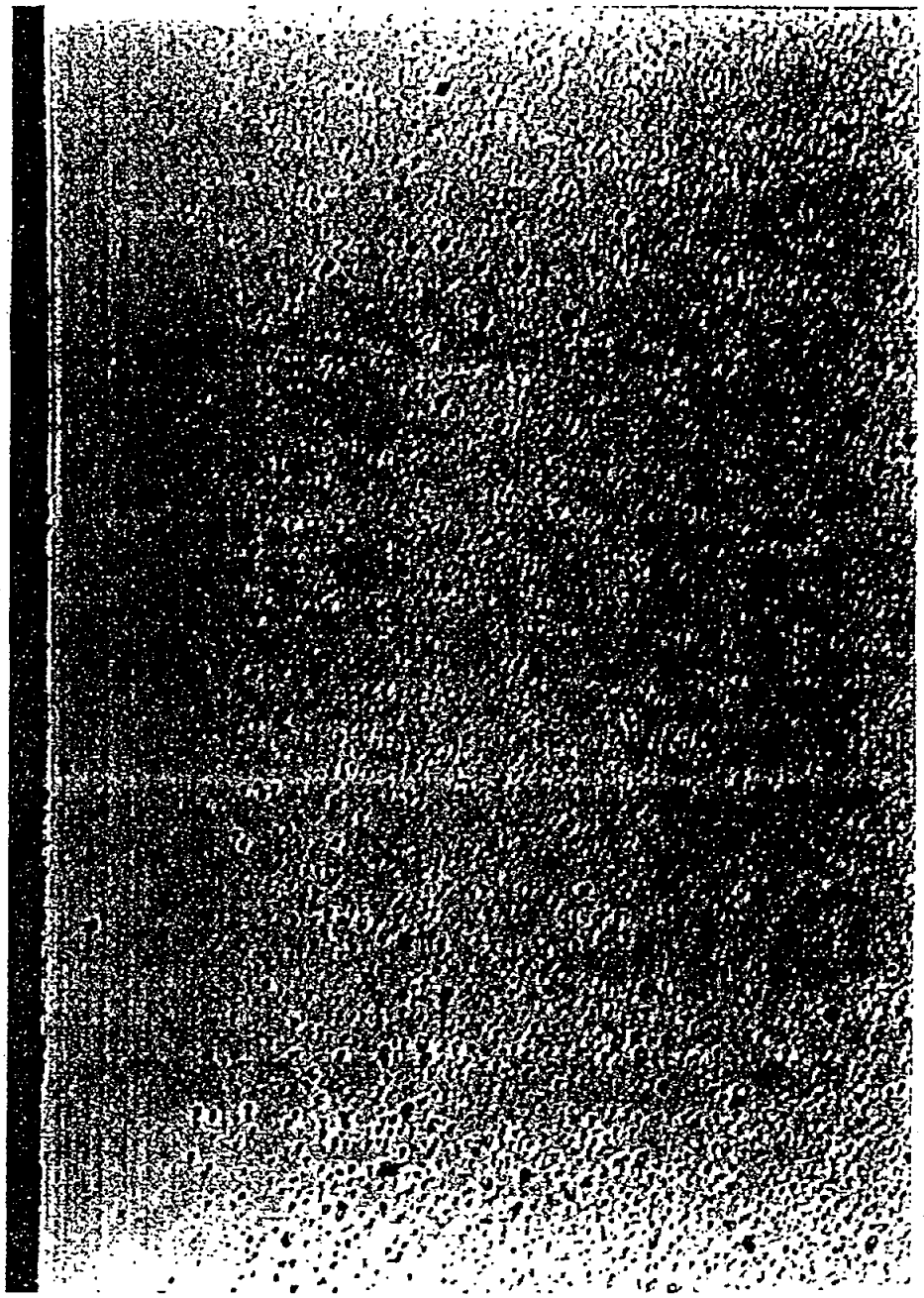


FIG. 9

FIG. 10

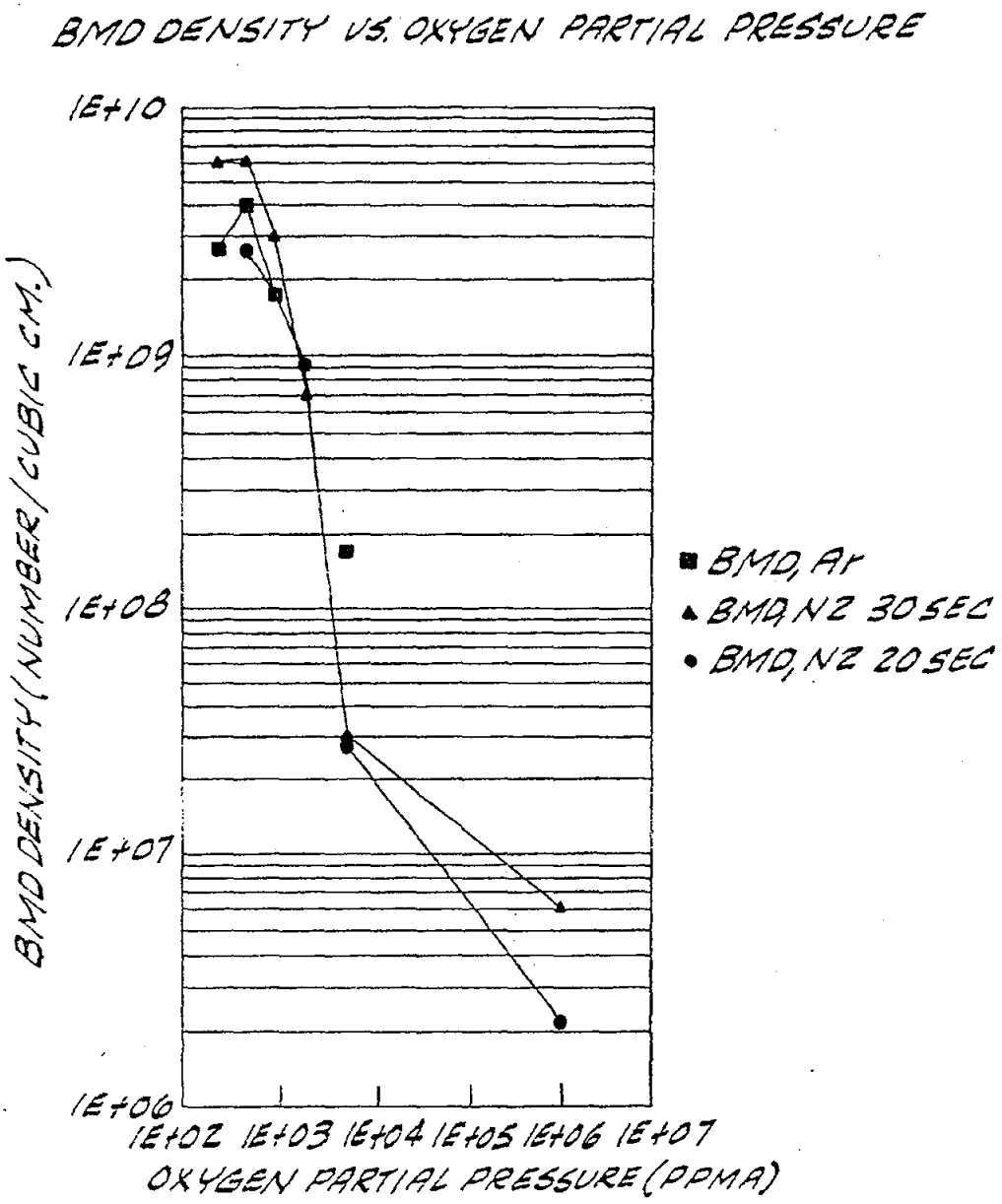

BMD DENSITY VS. OXYGEN PARTIAL PRESSURE
1E+10
1E+09
1E+08
1E+07
1E+06
BMD DENSITY (NUMBER/CUBIC CM.)
1E+02 1E+03 1E+04 1E+05 1E+06 1E+07
OXYGEN PARTIAL PRESSURE (PPMA)
BMD, Ar
BMD, N2 30SEC
BMD, N2 20SEC

FIG.11

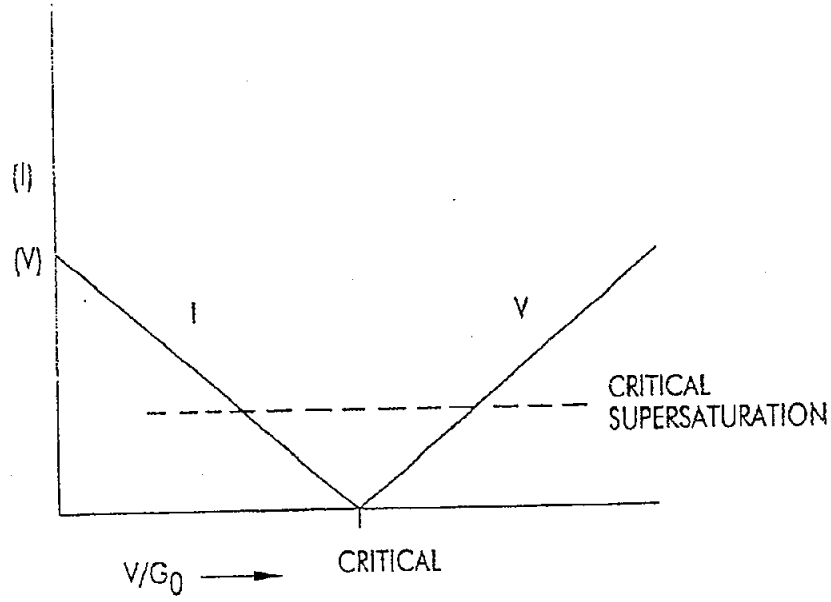

(I)
(V)
I
V
CRITICAL
SUPERSATURATION
V/G0
CRITICAL

FIG.12

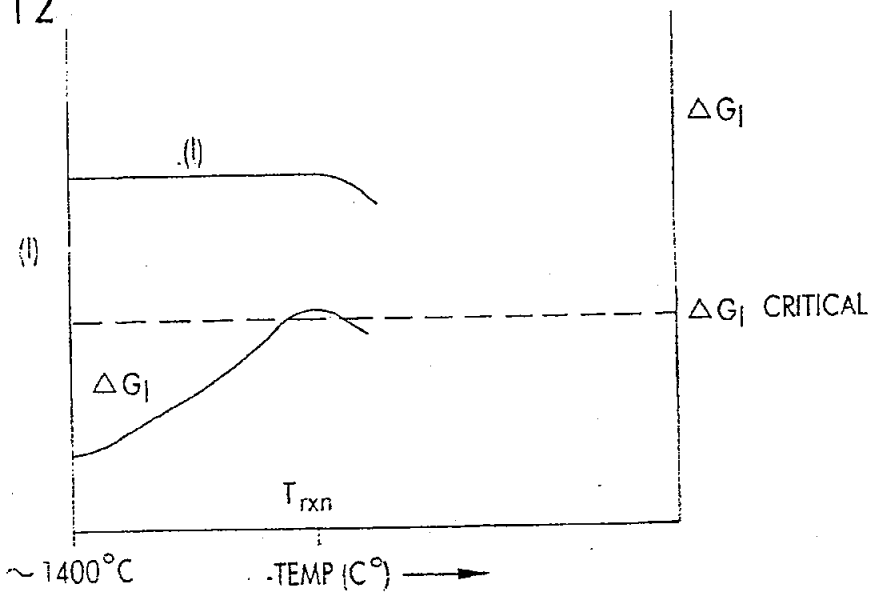

ΔGI
(I)
(I)
ΔGI CRITICAL
ΔGI
Trxn
~1400°C
-TEMP (C°)

FIG.13

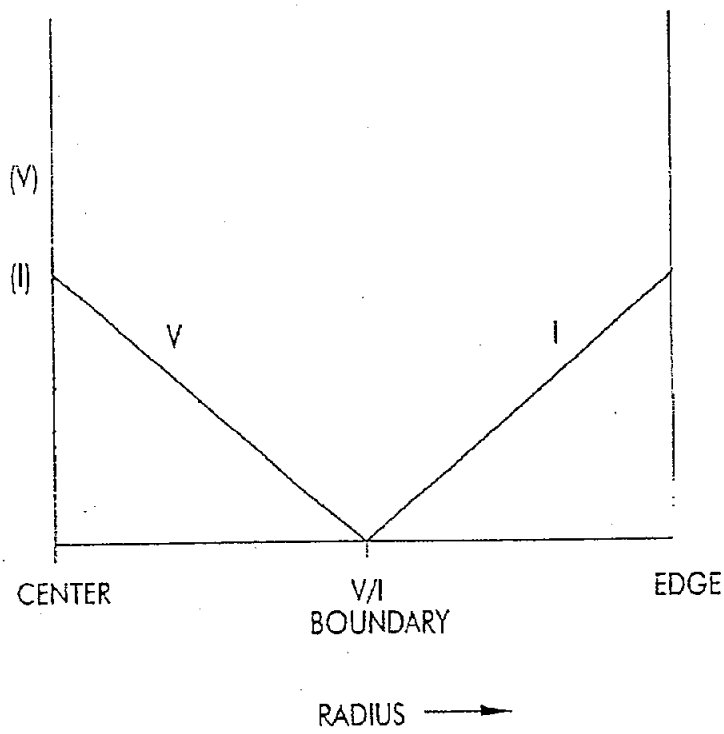

(V)
(I)
V
I
CENTER
V/I
BOUNDARY
EDGE
RADIUS

FIG.14

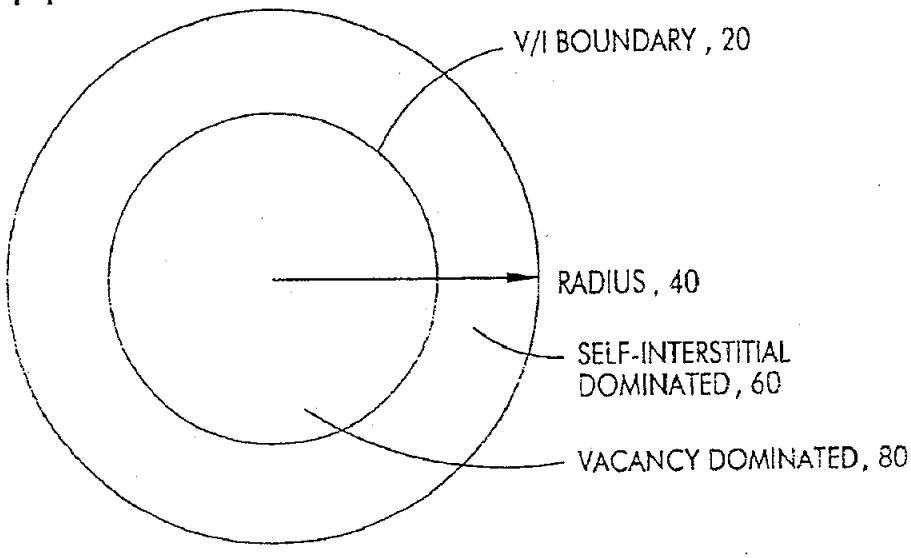
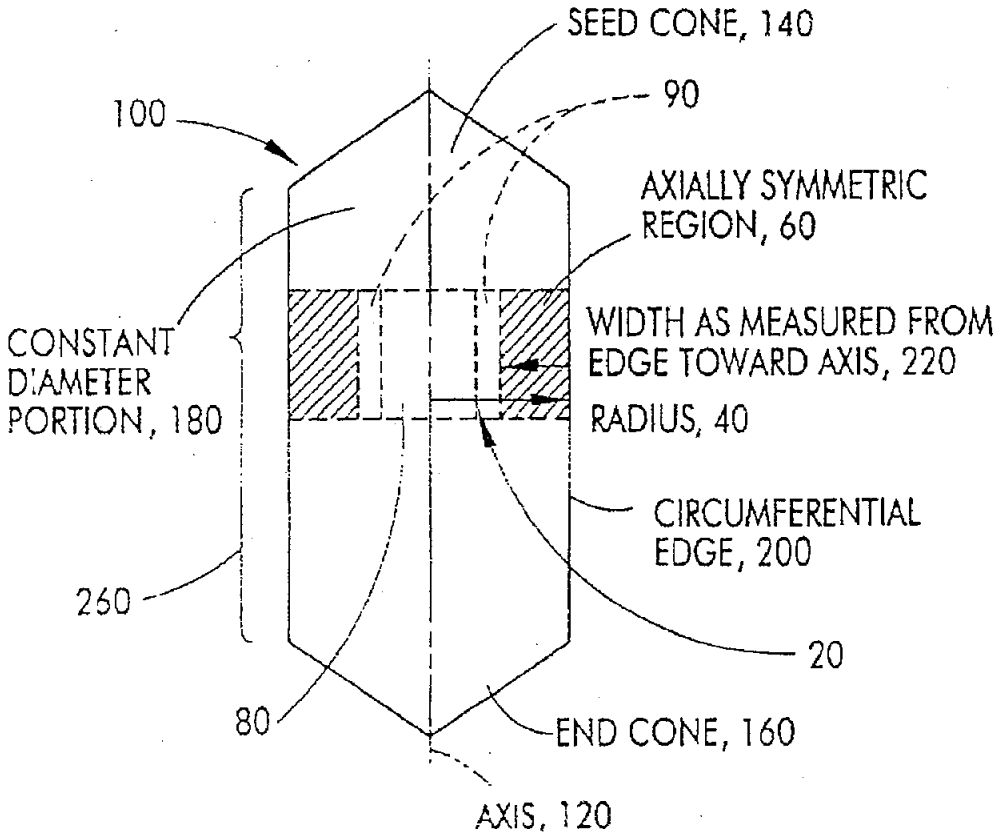

V/I BOUNDARY , 20
RADIUS , 40
SELF-INTERSTITIAL
DOMINATED , 60
VACANCY DOMINATED , 80

FIG.15


SEED CONE, 140
90
100
AXIALLY SYMMETRIC REGION, 60
WIDTH AS MEASURED FROM EDGE TOWARD AXIS, 220
CONSTANT DIAMETER PORTION, 180
RADIUS, 40
CIRCUMFERENTIAL EDGE, 200
260
20
80
END CONE, 160
AXIS, 120

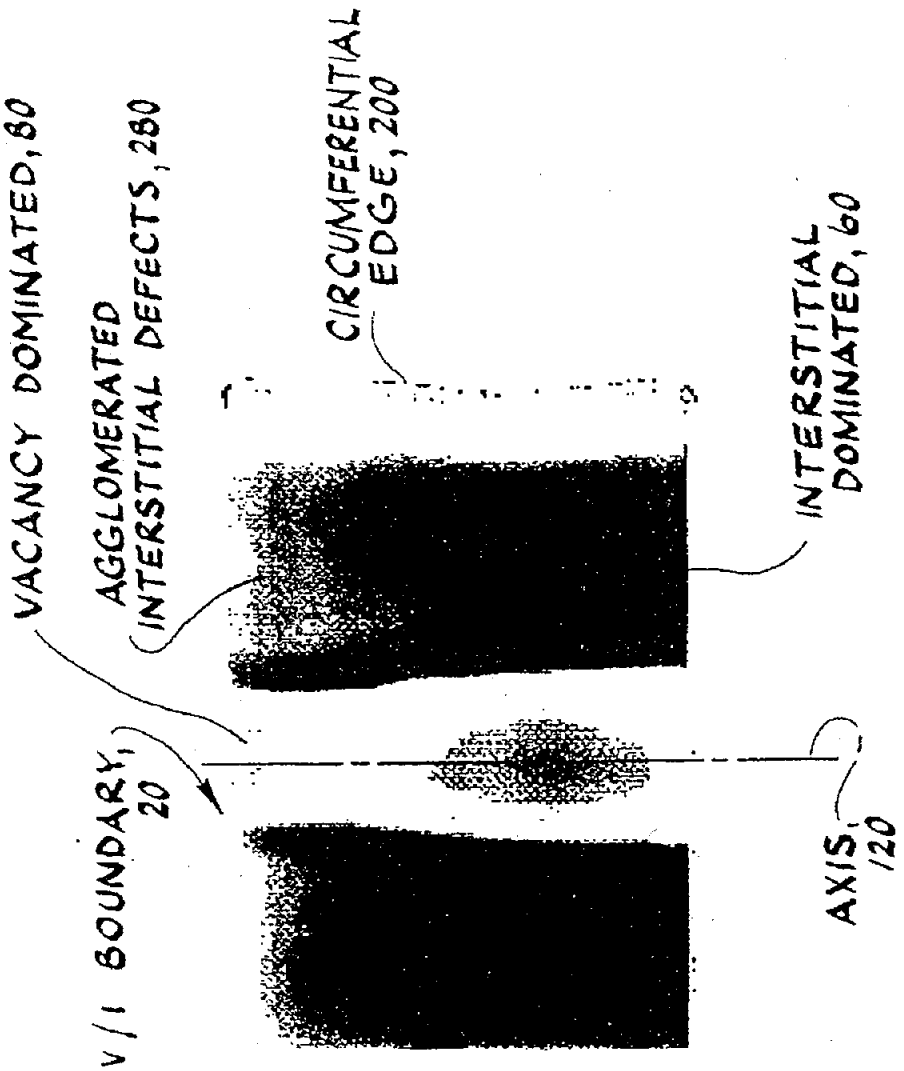

VACANCY DOMINATED, 80
AGGLOMERATED INTERSTITIAL DEFECTS, 280
CIRCUMFERENTIAL EDGE, 200
INTERSTITIAL DOMINATED, 60
V/I BOUNDARY, 20
AXIS, 120

FIG. 16

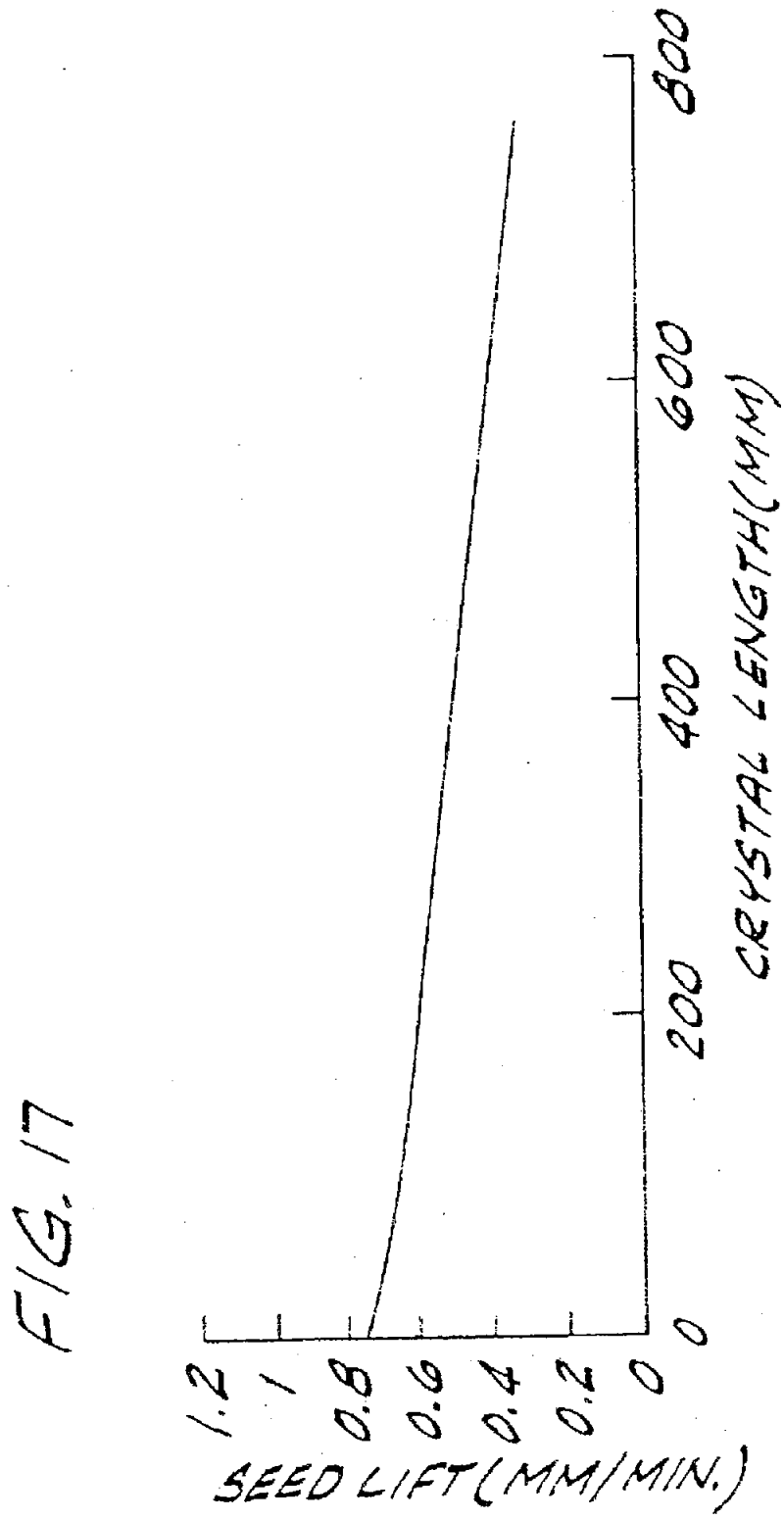

800
600
400
200
0
CRYSTAL LENGTH(MM)
1.2
1
0.8
0.6
0.4
0.2
0
SEED LIFT(MM/MIN.)

FIG. 17

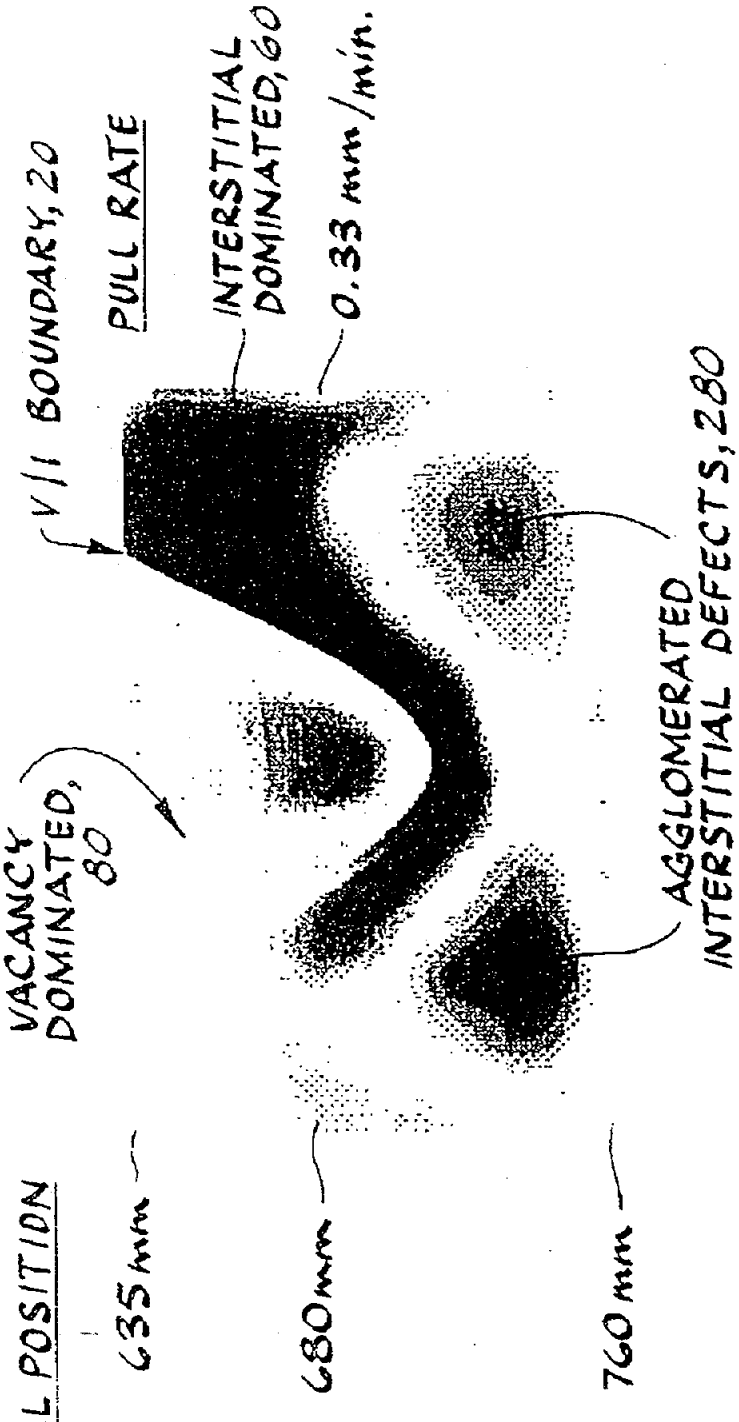

V/I BOUNDARY, 20
PULL RATE
INTERSTITIAL DOMINATED, 60
0.33 mm/min.
VACANCY DOMINATED, 80
AGGLOMERATED INTERSTITIAL DEFECTS, 280
AXIAL POSITION
635 mm
680 mm
760 mm

FIG. 18

FIG. 19

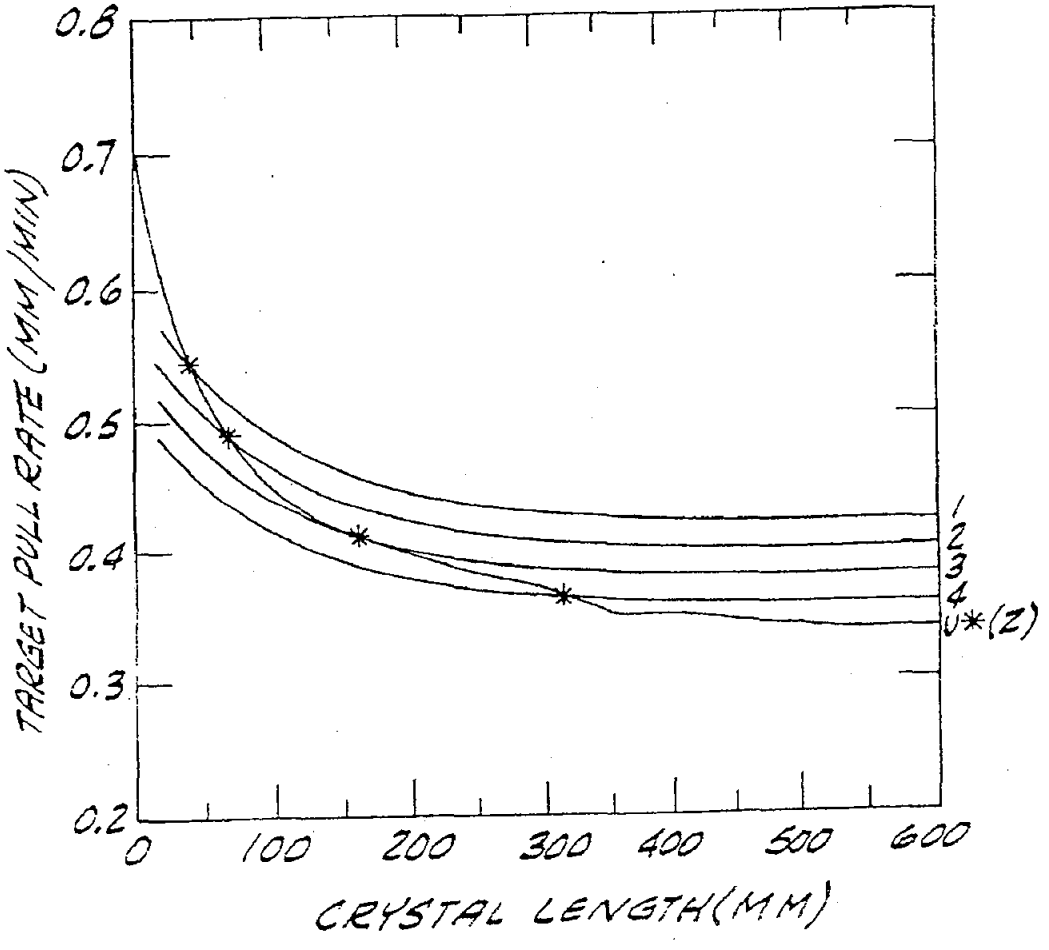

0.8
0.7
0.6
0.5
0.4
0.3
0.2
TARGET PULL RATE (MM/MIN)
0
100
200
300
400
500
600
CRYSTAL LENGTH(MM)
1
2
3
4
U*(Z)

FIG. 20

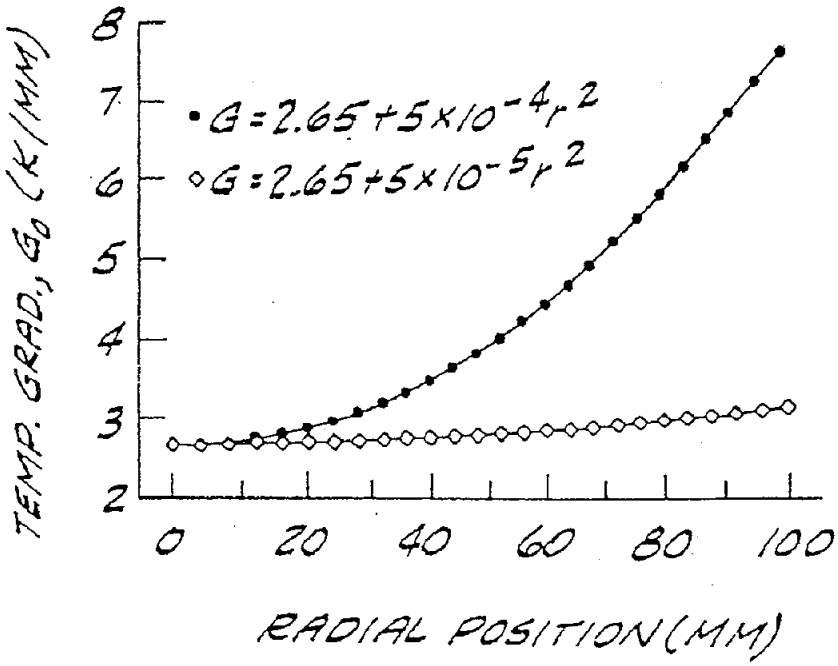

TEMP. GRAD., $G_0$ (K/MM)
8
7
6
5
4
3
2
• $G = 2.65 + 5 \times 10^{-4} r^2$
◇ $G = 2.65 + 5 \times 10^{-5} r^2$
0
20
40
60
80
100
RADIAL POSITION (MM)

FIG. 21

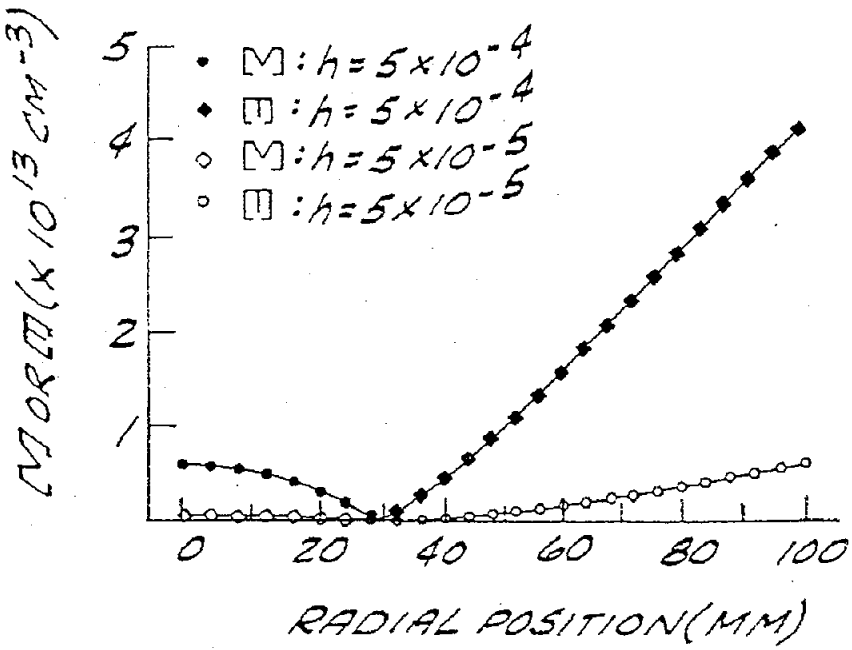

NORM ($\times 10^{13}$ CM$^{-3}$)
5
4
3
2
1
• M : $h = 5 \times 10^{-4}$
◆ ⊟ : $h = 5 \times 10^{-4}$
◇ M : $h = 5 \times 10^{-5}$
○ ⊟ : $h = 5 \times 10^{-5}$
0
20
40
60
80
100
RADIAL POSITION (MM)

FIG. 22

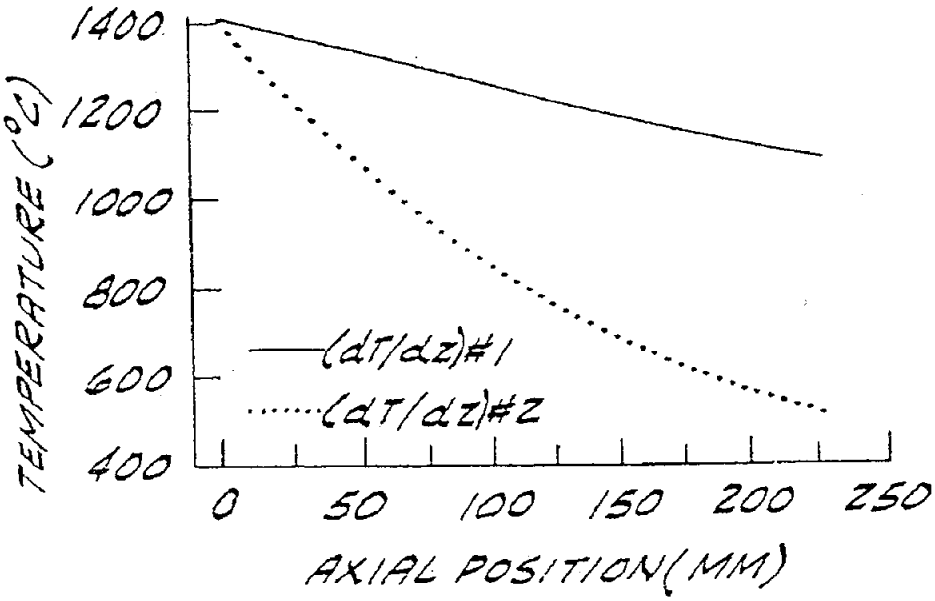
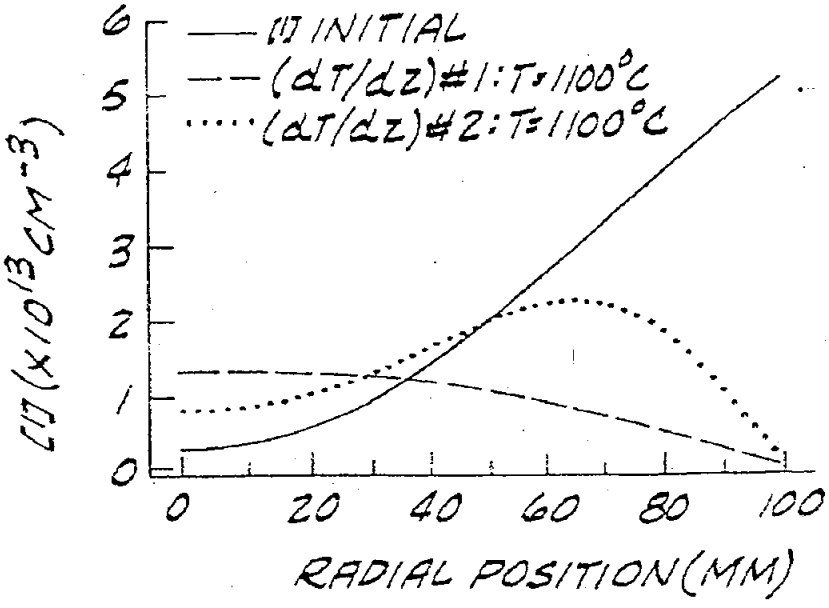

1400
1200
1000
800
600
400
TEMPERATURE (°C)
(dT/dz)#1
(dT/dz)#2
0
50
100
150
200
250
AXIAL POSITION(MM)

FIG. 23


[I] INITIAL
(dT/dz)#1: T=1100°C
(dT/dz)#2: T=1100°C
[I] (X10^13 CM^-3)
6
5
4
3
2
1
0
0
20
40
60
80
100
RADIAL POSITION(MM)

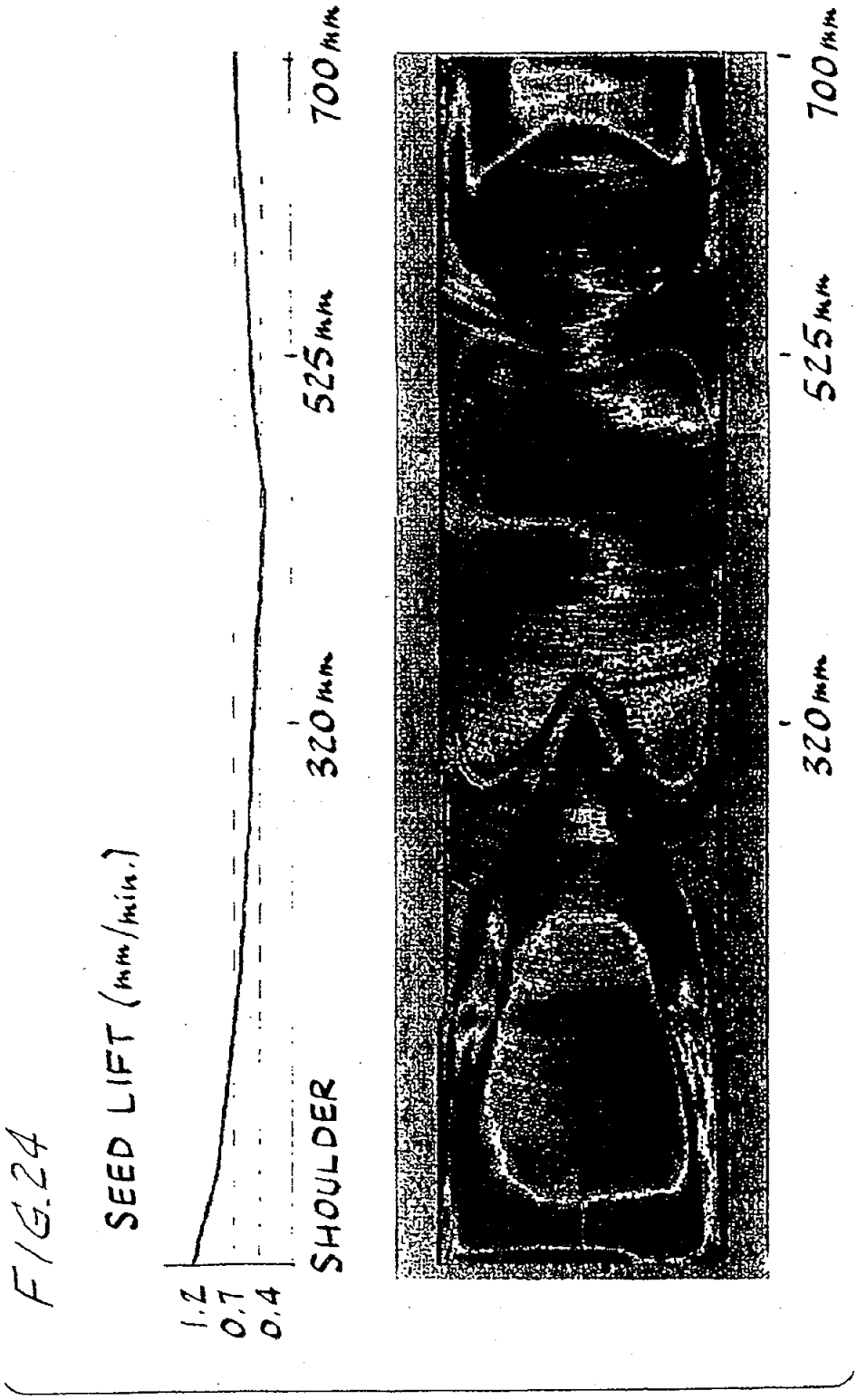
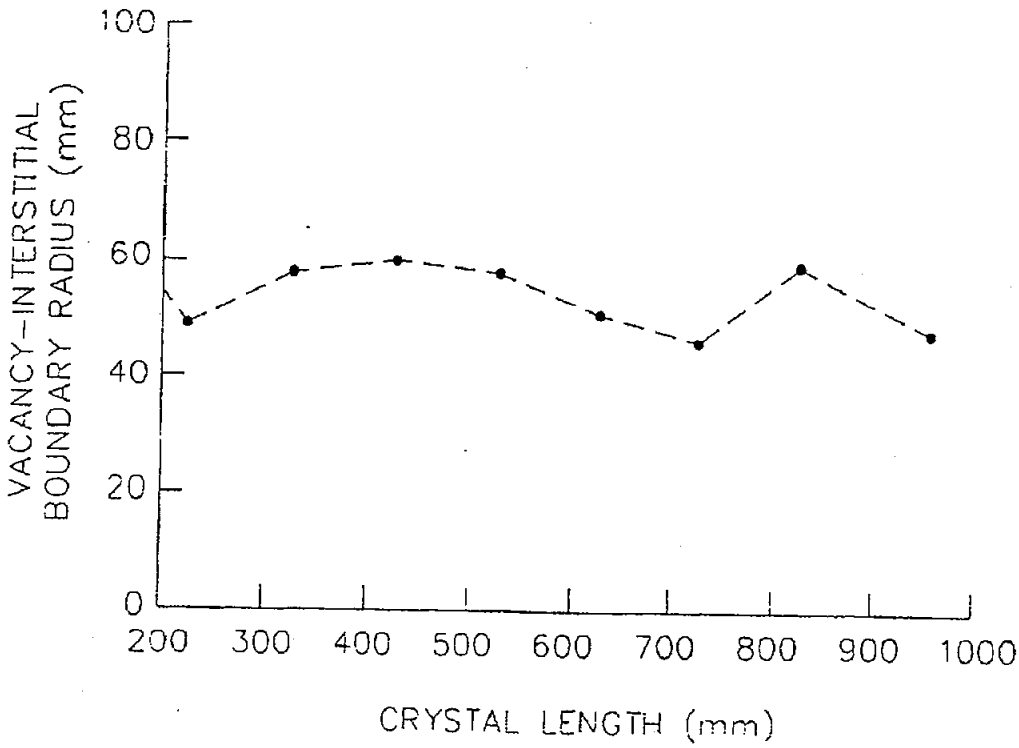

SEED LIFT (mm/min.)
1.2
0.7
0.4
SHOULDER
320 mm
525 mm
700 mm
320 mm
525 mm
700 mm

FIG.24

FIG. 25


VACANCY-INTERSTITIAL BOUNDARY RADIUS (mm)
100
80
60
40
20
0
200
300
400
500
600
700
800
900
1000
CRYSTAL LENGTH (mm)

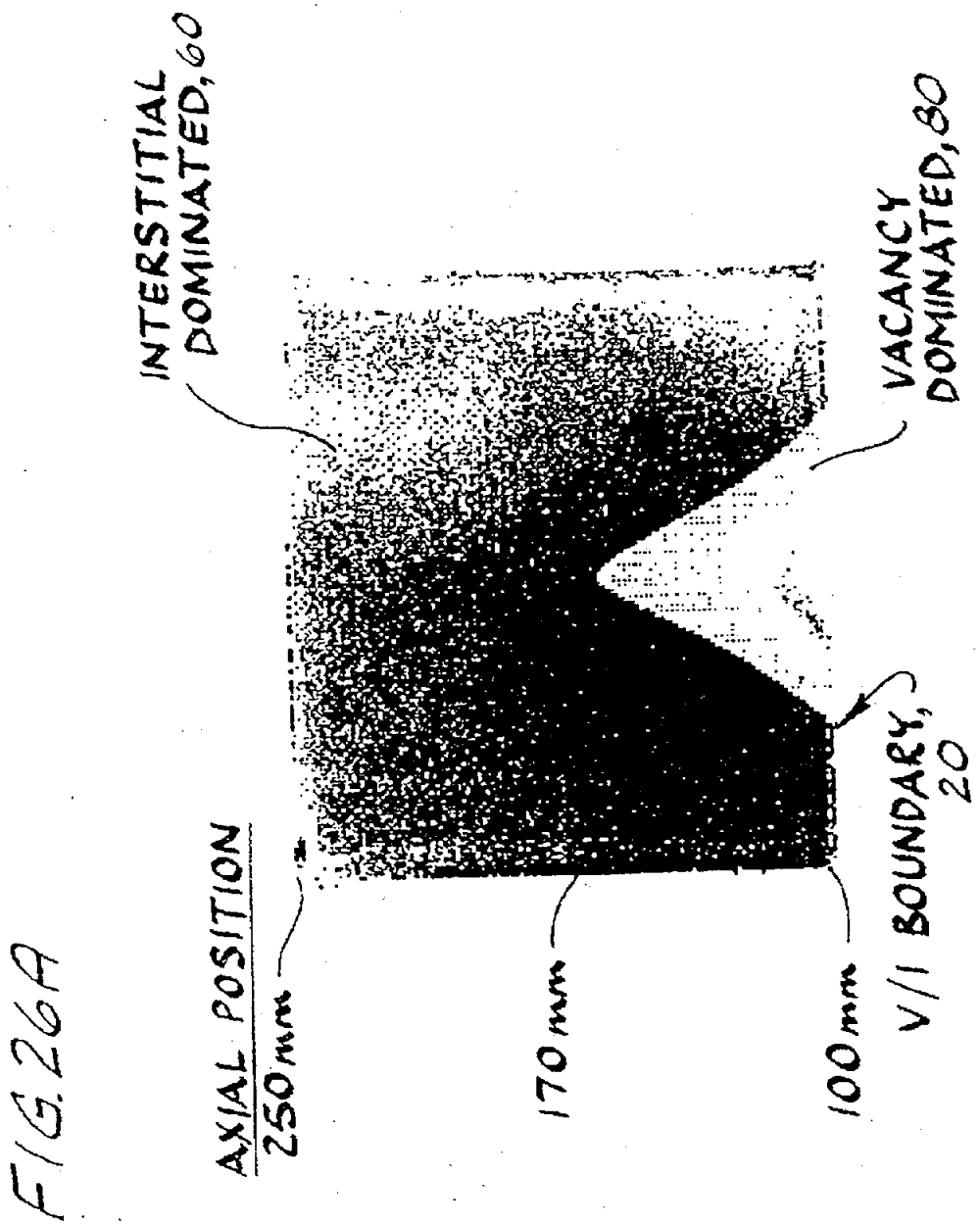

INTERSTITIAL DOMINATED, 60
VACANCY DOMINATED, 80
V/I BOUNDARY, 20
AXIAL POSITION
250 mm
170 mm
100 mm

FIG. 26A

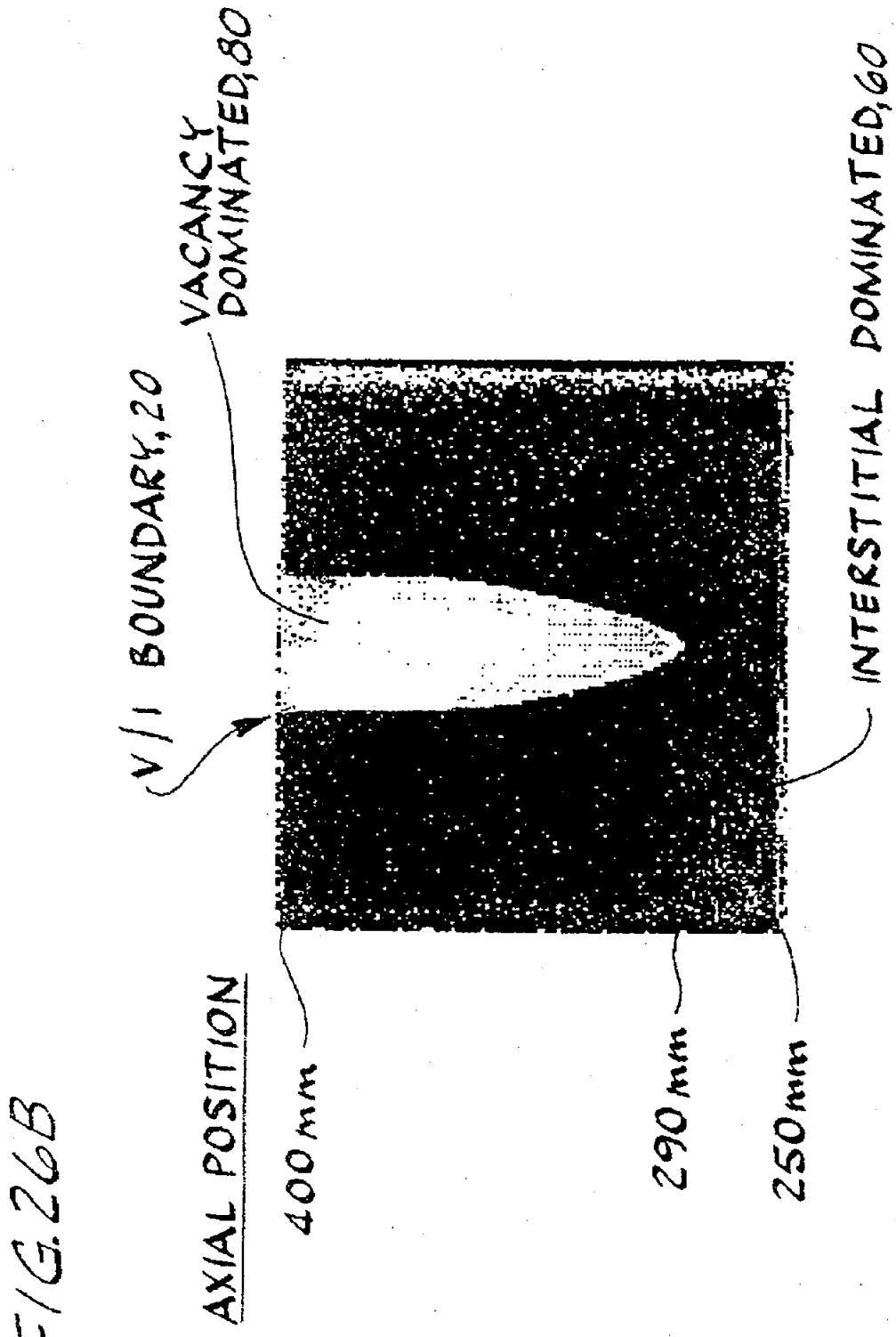

V/I BOUNDARY, 20
VACANCY DOMINATED, 80
INTERSTITIAL DOMINATED, 60
AXIAL POSITION
400 mm
290 mm
250 mm

FIG. 26B

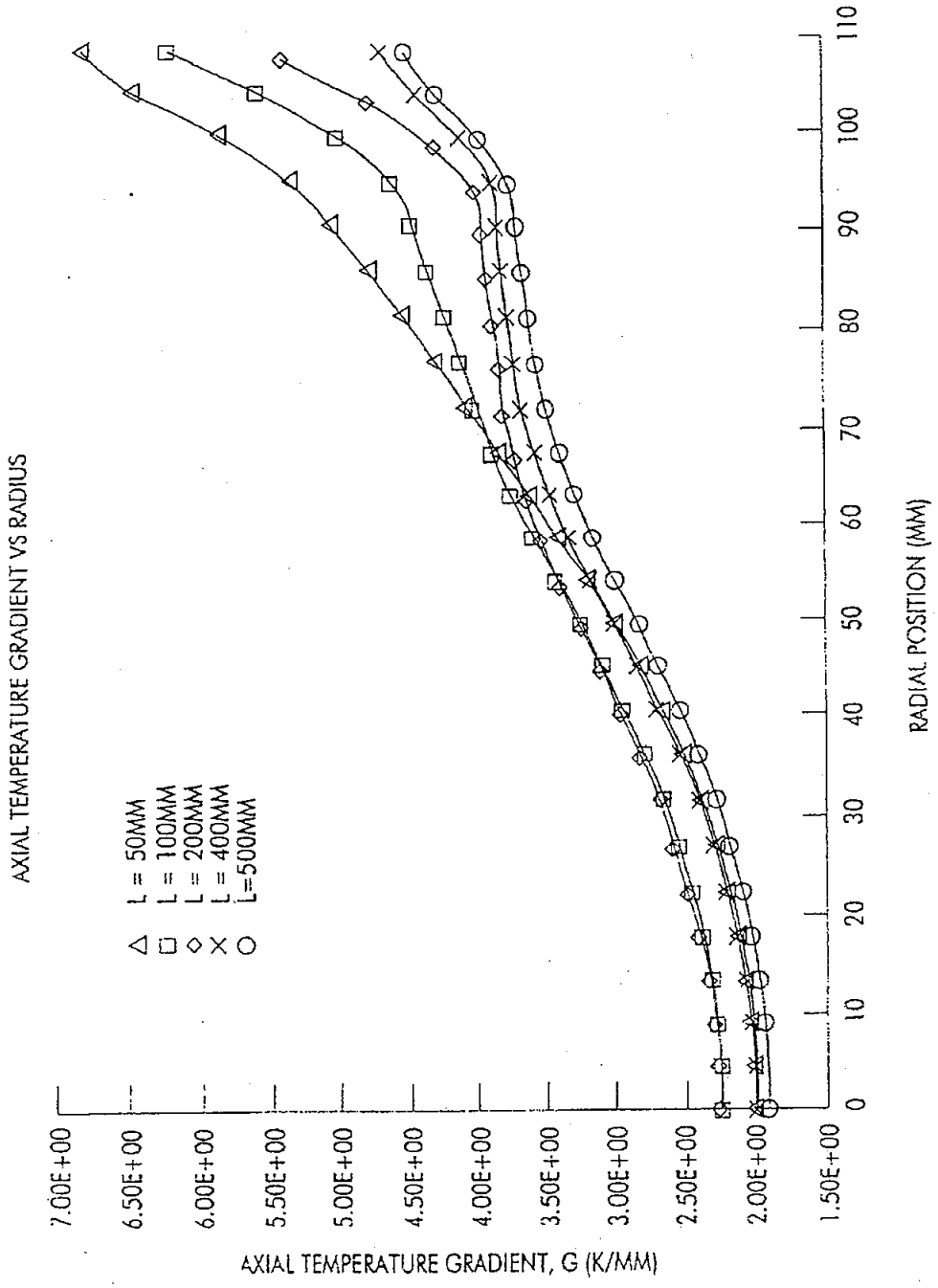

AXIAL TEMPERATURE GRADIENT VS RADIUS
L = 50MM
L = 100MM
L = 200MM
L = 400MM
L=500MM
AXIAL TEMPERATURE GRADIENT, G (K/MM)
7.00E+00
6.50E+00
6.00E+00
5.50E+00
5.00E+00
4.50E+00
4.00E+00
3.50E+00
3.00E+00
2.50E+00
2.00E+00
1.50E+00
RADIAL POSITION (MM)
0
10
20
30
40
50
60
70
80
90
100
110

FIG.27

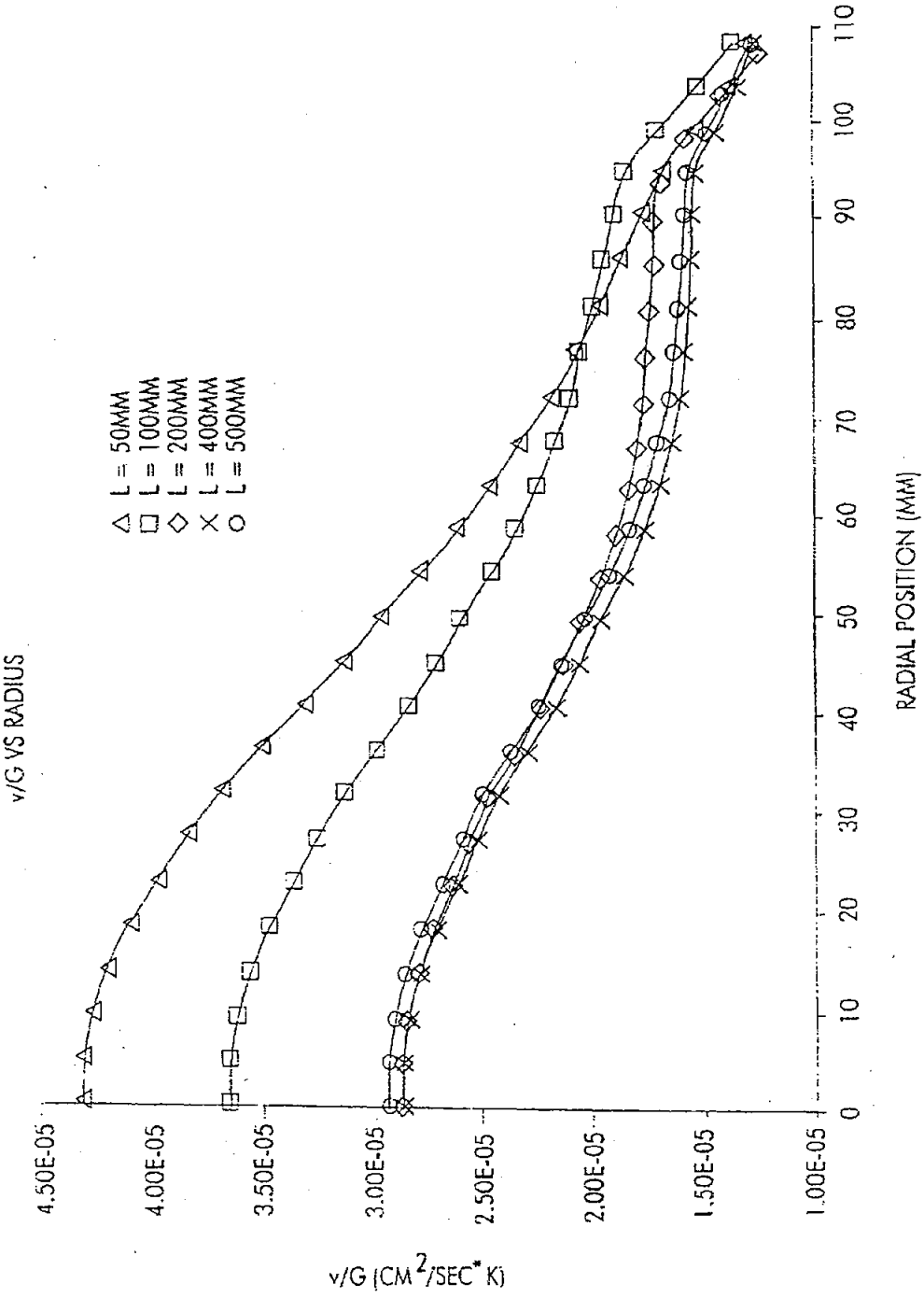
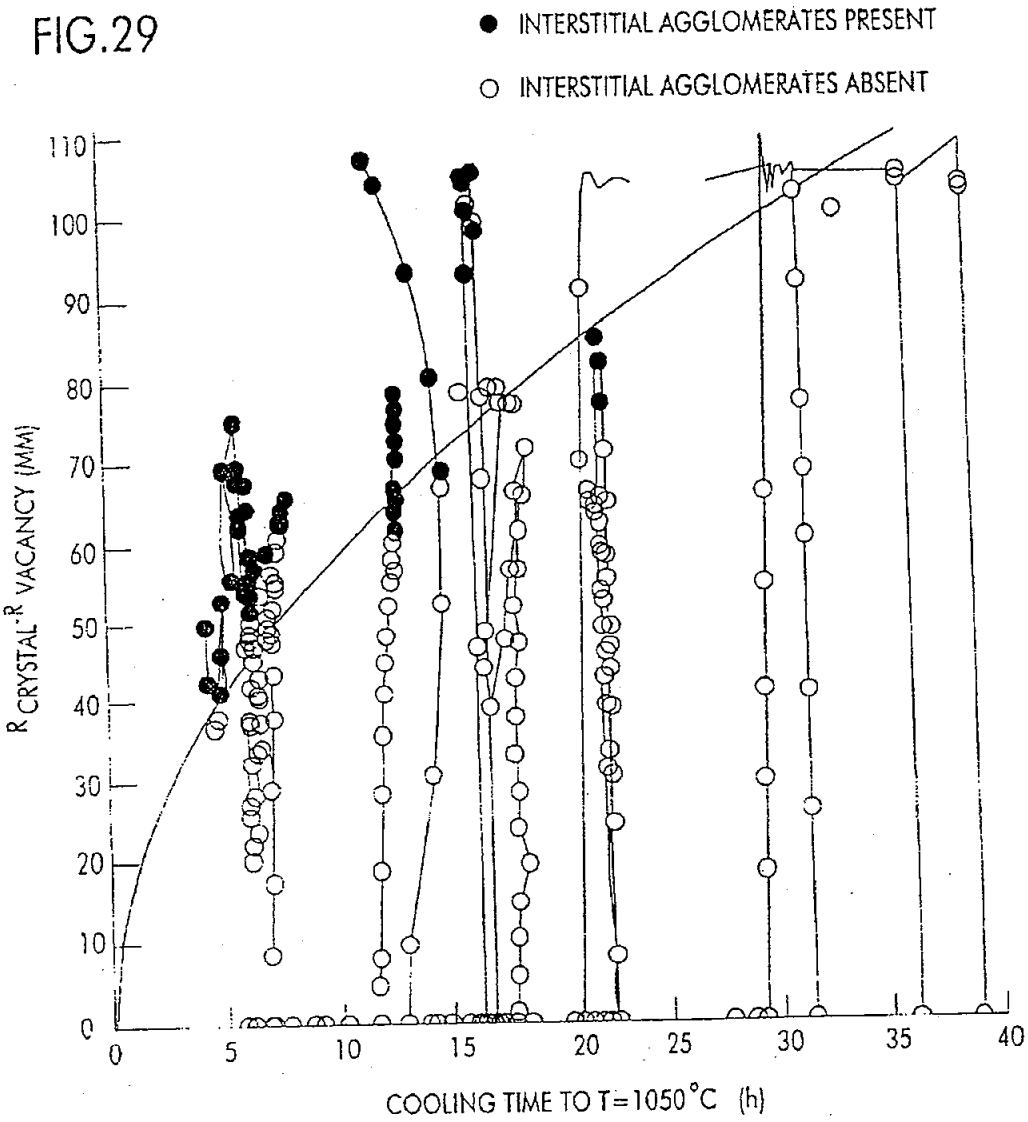

v/G VS RADIUS
L = 50MM
L = 100MM
L = 200MM
L = 400MM
L = 500MM
4.50E-05
4.00E-05
3.50E-05
3.00E-05
2.50E-05
2.00E-05
1.50E-05
1.00E-05
v/G (CM 2/SEC* K)
0
10
20
30
40
50
60
70
80
90
100
110
RADIAL POSITION (MM)

FIG.28

FIG.29


INTERSTITIAL AGGLOMERATES PRESENT
INTERSTITIAL AGGLOMERATES ABSENT
R CRYSTAL-R VACANCY (MM)
110
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
COOLING TIME TO T=1050°C (h)